

Systems Engineering for Systems of Systems

Experience, Issues and Next Steps

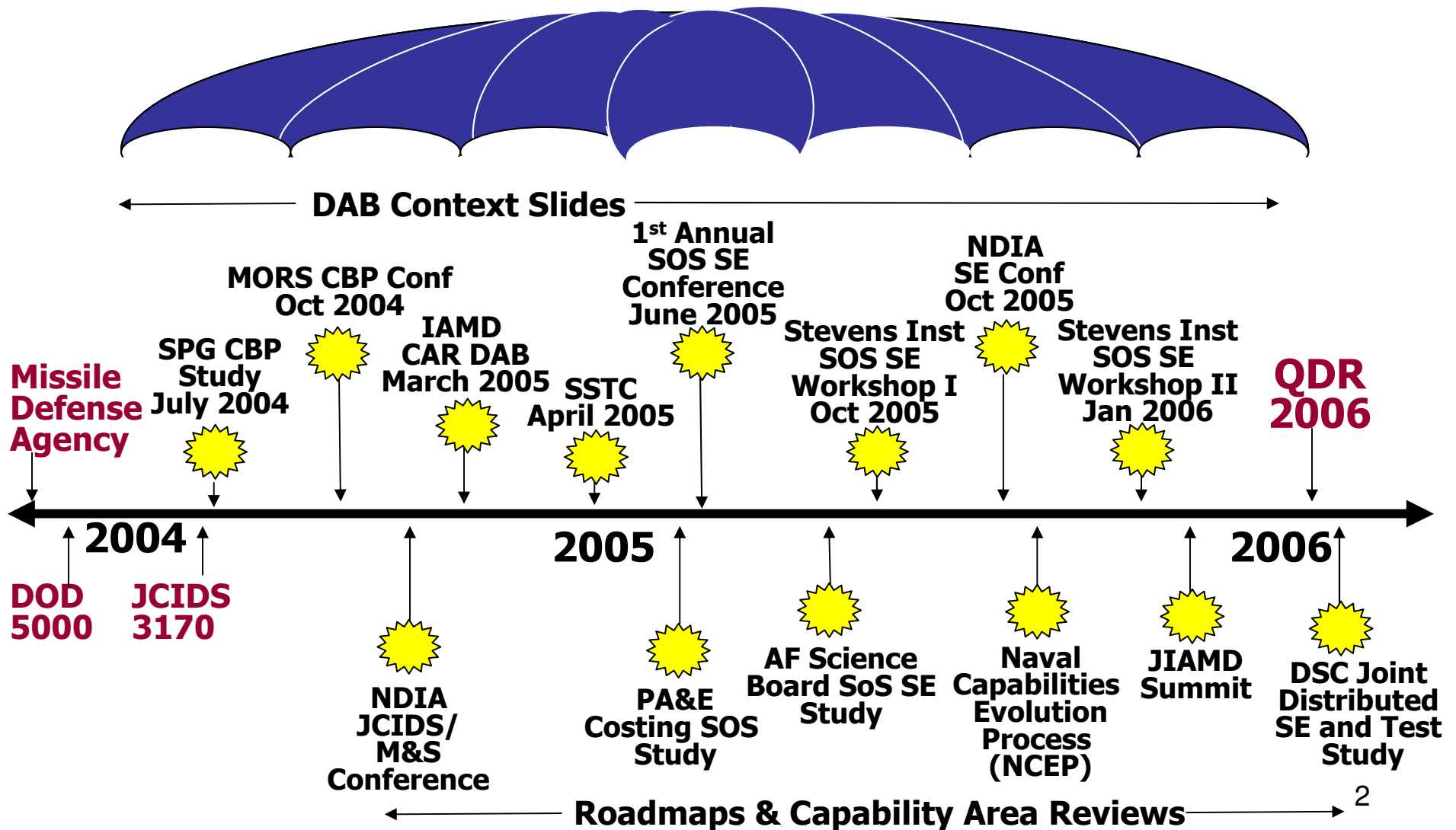
Systems and Software Technology Conference
Salt Lake City
May 3, 2006

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Umbrella View

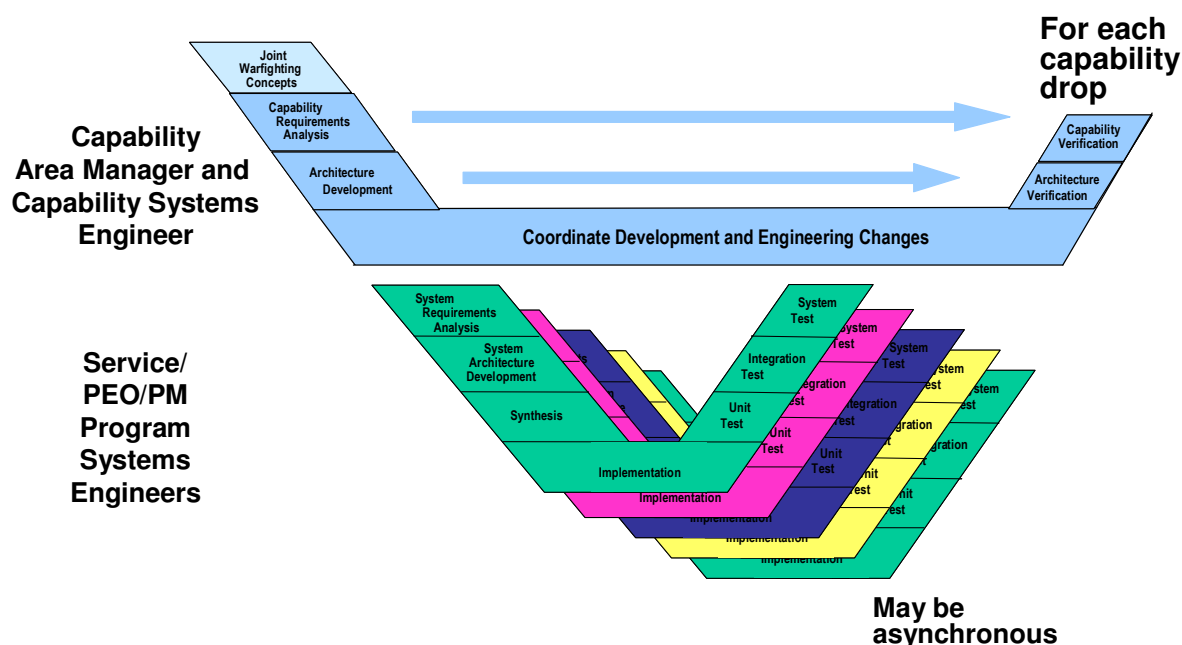
Evolving Perspectives on SOS SE



September 2004 – MORS CBP I

Systems Engineering Implications of JCIDS

CAM/CSE Activities and the Stacked V's



- Early recognition that to respond to CBP and JCIDS, acquisition process needs to address the m
 - Management of the collection of systems/ systems upgrades required to address user capabilities
 - Systems engineer at the capability level
- Identified a set of SE actions to be addressed during the transition from JCIDS to acquisition for SOS

March 2005 - SSTC

DOD Capability Based Approach Implications for Systems Engineering*

- **SE begins with JCIDS**

- FAA, FNA, and FSA are the start of SE
- JCIDS participation is primarily from the uniformed-side
- SE can help in feasibility analysis

- **Capabilities are addressed at multiple levels**

- Initial Capabilities Documents can be systems- or SoS- focused
- Complex relationships among needs and solutions (JCDs, ICDs, CDDs)

- **Engineering and design of increments of capability need to consider uncertainties of future needs in system design**

- Calls for open, extensible systems approaches which can support future, yet to be defined, increments

- **Capabilities will be satisfied by a grouping of legacy, new programs, and technology insertion**

- Solutions must be designed, developed, and tested against capability area benchmarks (not optimized at the system level)

- **A capability will cross Service boundaries**

- Who is the Capability sponsor?
- Who maintains prioritization and funding?
- Where is Capability-level SE performed?

- Further discussion of the

- Considerations which call for an SE in capabilities definition from the outset of the CBA

- e.g. need to assure that new systems acquisition produce systems which work with existing systems to meet capability needs

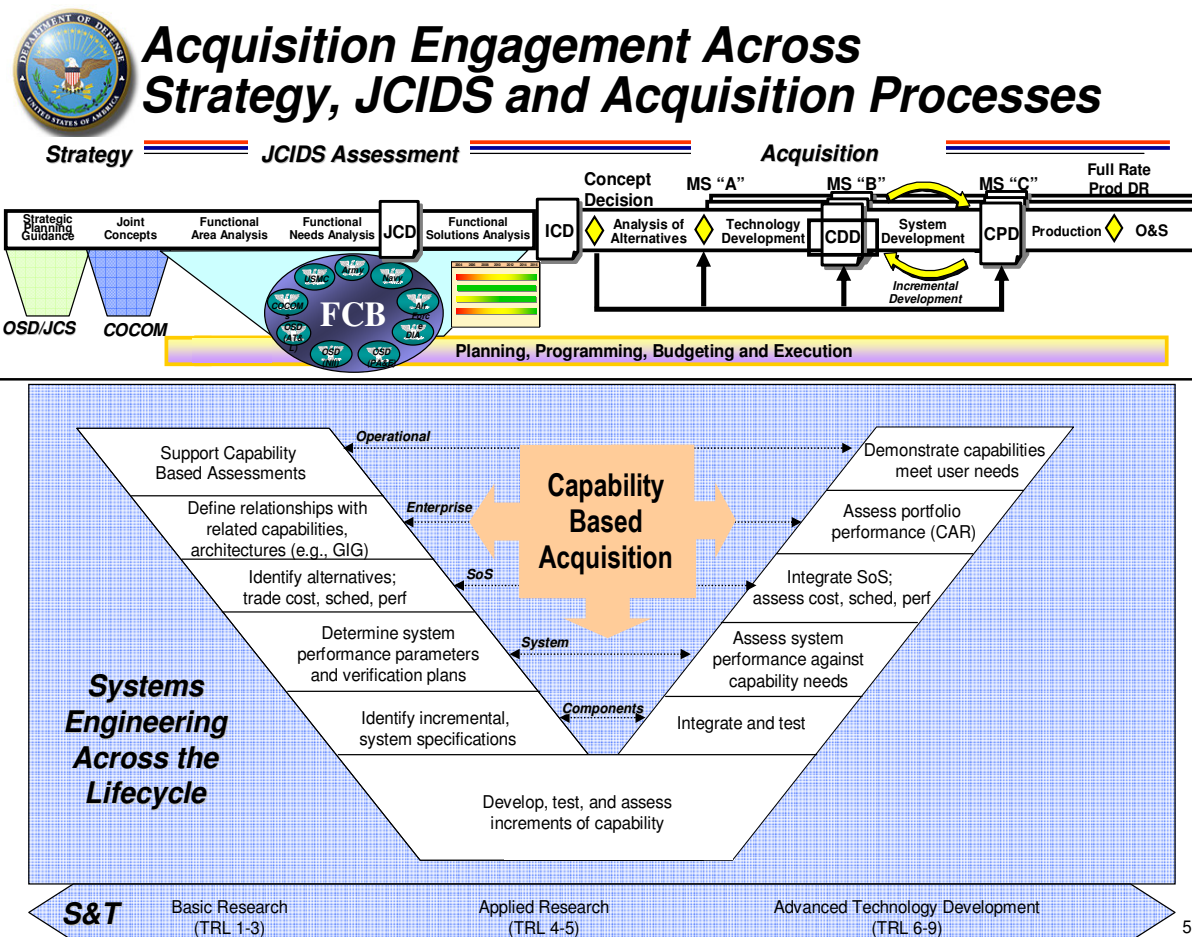
- Implications for systems

- e.g. optimize at capability vs systems level

- Organizational/ management issues

- e.g. cross Service boundaries

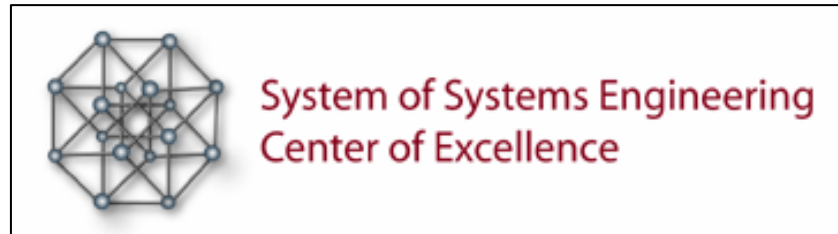
October 2005 – NDIA SE Conference Systems Engineering to Enable Capabilities Based Planning*



- Extend to Enterprise-Wide Systems Engineering view
 - Organizational efforts that focus on strategic objectives through
 - Investment decisions
 - Architecture principles
 - Standards and protocols
 - Engineering practices
 - Measured, and/or motivated by a different set of priorities
 - Goal-oriented, organizational and stakeholder issues
 - Characterized by multiple constituents with different goals and priorities
 - Requires systems engineering application to address multiple systems and SoS constraints and objectives

* Baldwin, AT&L Defense Systems

June 2005
1st Annual SOS SE Conference



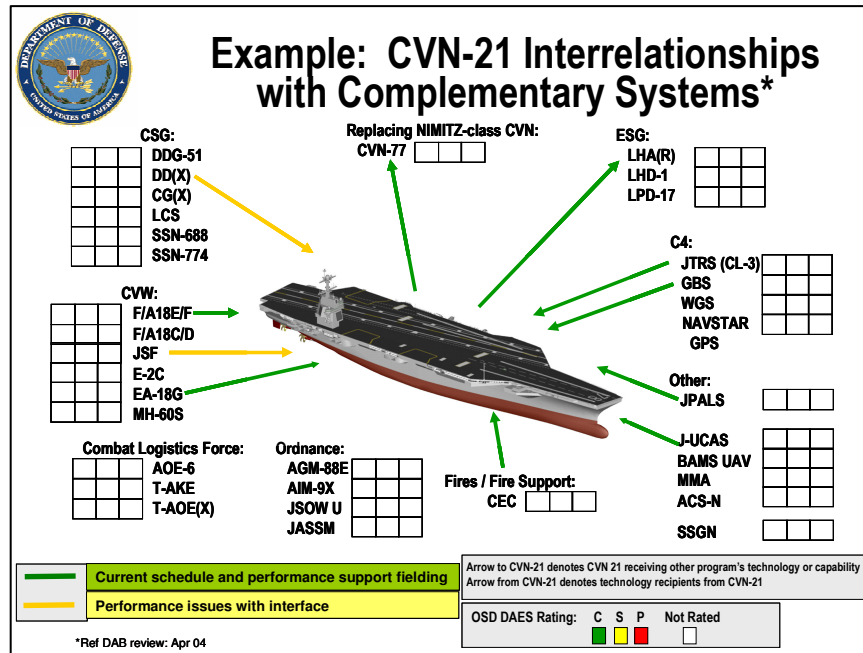
- Sponsored by AT&L DS Systems Mission Integration (SMI)
- Brought together a range of organizations addressing SOS from different perspectives
- Illustrated a strong interest in the SOS area
- Demonstrated the breadth of views about the salient aspects of SOS and different ways to approach SOS theory, management and technology

Stevens Institute of Technology

SOS SE Workshops (Oct 05 and Jan 06)

- Participants from government, industry, FFRDCs, academia
- Focused on technical issues (not management)
- Workshop Accomplishments:
 - Broad look at impacts of complexity of systems
 - Characterized SE Process for SoS
 - Addressed Testing and Sustainment for SoS
- General implications of SE at an SOS level:
 - Traditional SE process is the same for SoS, but the application is different
 - Special case of functional allocation: Allocate functionality to systems which are known to provide needed functionality
 - Many unknowns with component systems (e.g. Limited design documentation)
 - Early emphasis on 'discovery' versus design
 - Can you execute SOS in a "big bang" approach?
 - Never; SOS developments will inevitably be incremental improvements to existing component systems

AT&L DAB Context Slides



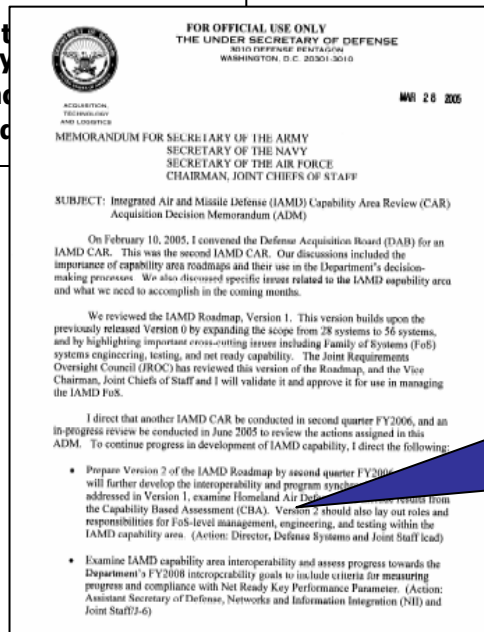
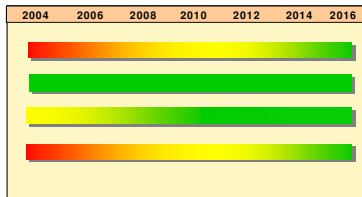
- Context slides showing system interdependencies are prepared for each DAB review
 - To date ~25+ context slides have been developed
- Show programmatic interdependencies for
 - Individual systems
 - Across the portfolio of Major Defense Acquisition Programs (MDAPs)

Capability Roadmaps

Common Roadmap Content

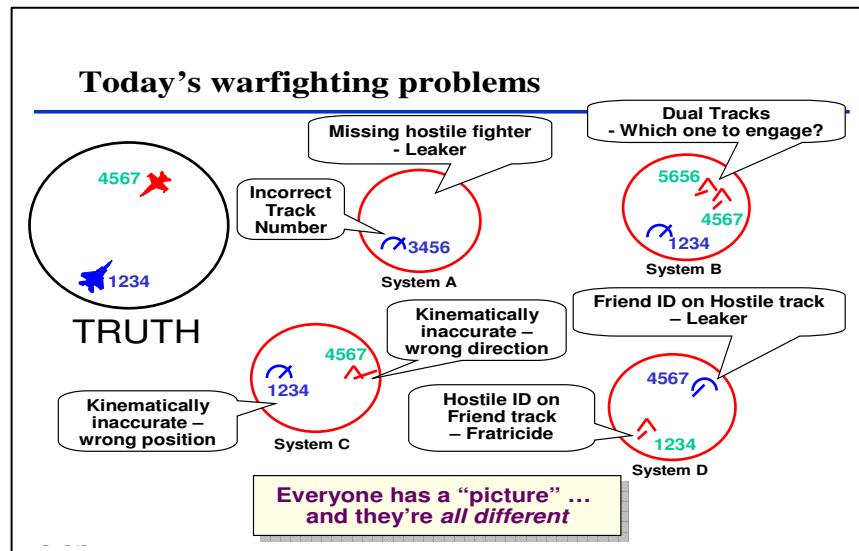
Chapter 1 – Introduction
 Chapter 2 – Policy
 Chapter 3 - Operational Concept, Joint Mission Threads
 Chapter 4 - **Systems Engineering and Integrated Architectures**
 Chapter 5 - Program Evolution
 Chapter 6 - Key Initiatives and Coalition Initiatives
 Chapter 7 - Capability Development and Integration Management
 Chapter 8 - Implementation of the DoD Net-centric Data Strategy
 Chapter 9 - Net-Centric Underpinnings to JBMC2
 Chapter 10 - Experimental Technology
 Chapter 11 - Joint Test and
 Chapter 12 - Summary and

- Based on DOD 5000, there are a number of capability roadmaps underway
- These roadmaps each have identified SE issues and address SE in different ways
- In IAMD Roadmap in particular, DAB direction focuses on roles and responsibility for capability level management, SE and test

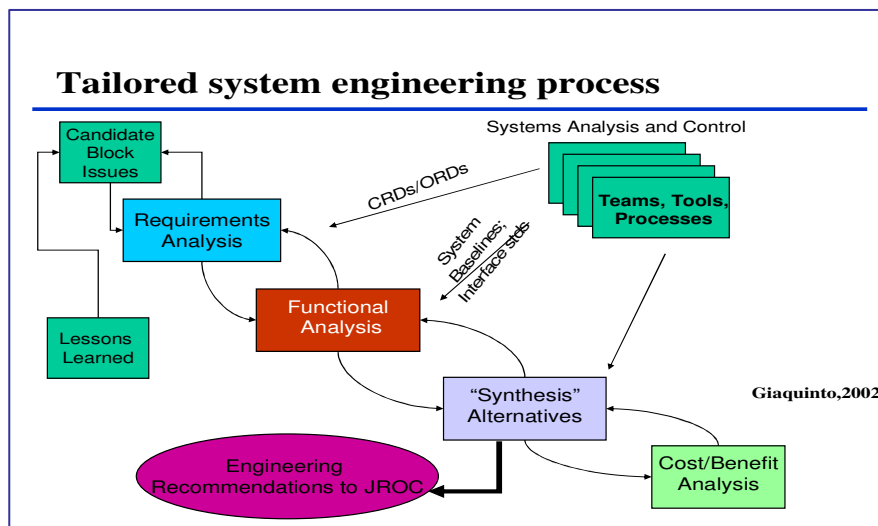


"Version 2 should also lay out roles and responsibilities for FOF-level management, engineering, and testing within the IAMD capability area"
 March 2005, IAMD CAR ADM

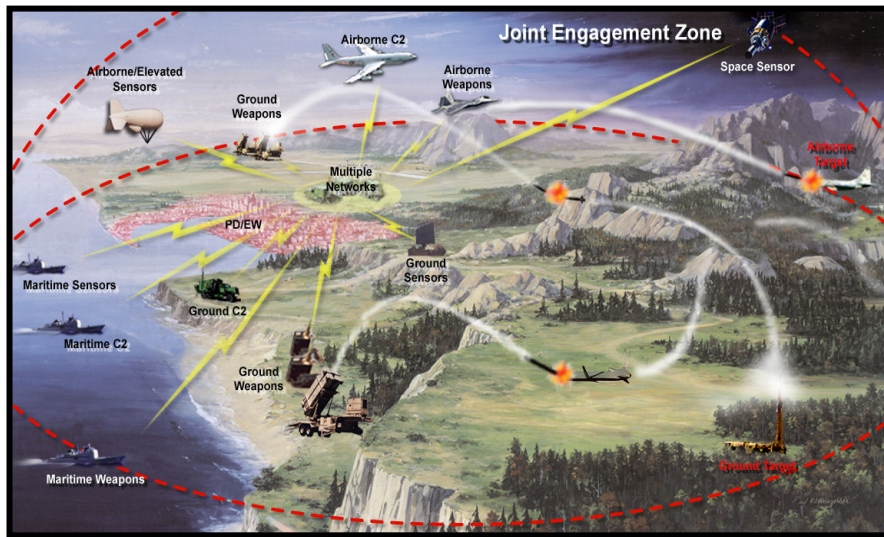
Single Integrated Air Picture



- Achieving a common air picture across multiple platforms and sensors is a DOD objective
- The Joint SIAP SE Office (JSSEO) has been addressing the SE issues of this cross systems capability need
- JSSEO experience exemplifies the management and technical issues of SE of a cross cutting enabling capability which
 - Requires cooperation and active engineering participation
 - From systems owned and funded by all the Services
 - Which play a critical role in Service as well as the Joint environment



Joint Integrated Air and Missile Defense JIAMD Summit FOS/SOS FACT

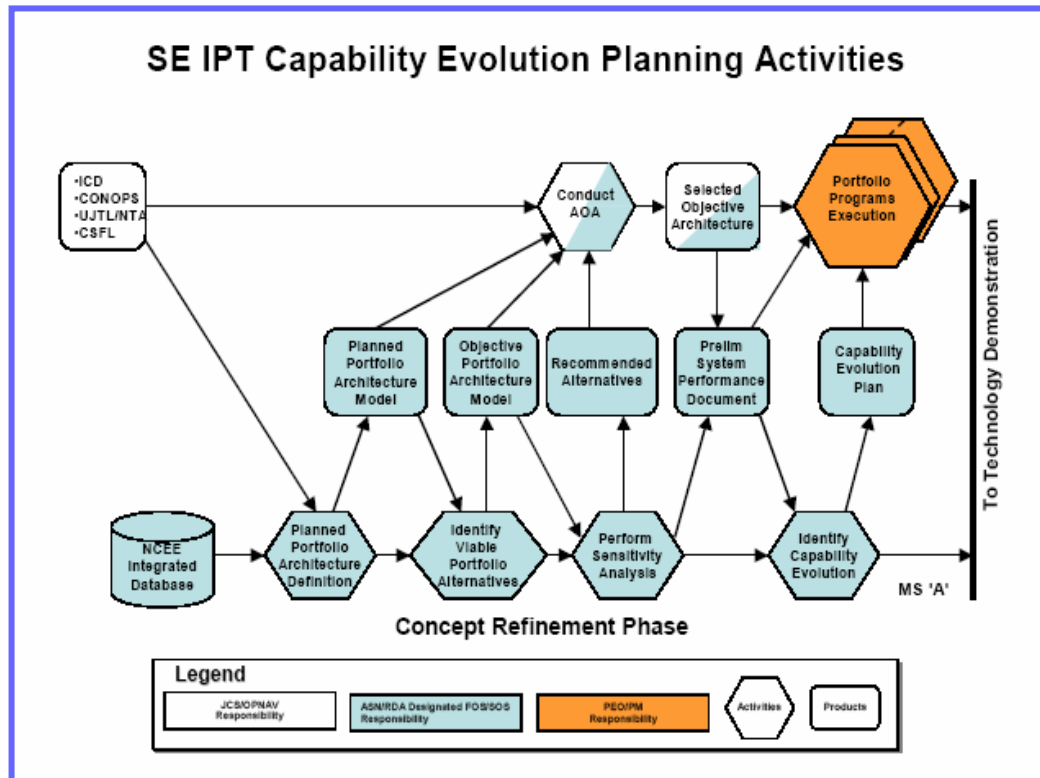


Examined FOS/SOS issues in integrated air and missile defense mission, with a particular look at the Missile Defense Agency joint management and execution model for the Ballistic Missile Defense System

- In 2004, MDA was given control over requirements, resources and acquisition of capabilities needed for the BMDS
 - Created a SE organization and process
- Despite the freedom from organizational issues, many of the considerations raised in the SOS SE discussions are faced in the MDA case
 - Systems which are components in BMDS continue to have independent uses with needs and development and testing scheduled
 - Issues of CM and sustainment apply here as well
 - Complexity of the components mean that there is continued 'discovery' wrt interactions among systems when placed in larger context

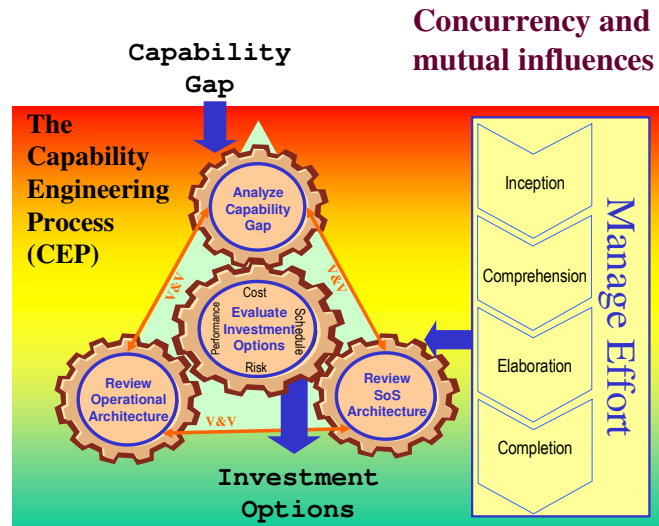
SE Forum

Naval Capabilities Evolution Process*



- Draft guidance for SOS SE for Navy SOS (i.e. Mission Capability Packages (MCPs))
 - Presented to SE Forum
- Recommends a process to
 - Delineate requirements for at capability level
 - Decompose these into needed functionalities and performance characteristics
 - Identify and assess current capabilities to meet the functionality needs of higher level capability
- Based on some initial use cases
- Now out for comment

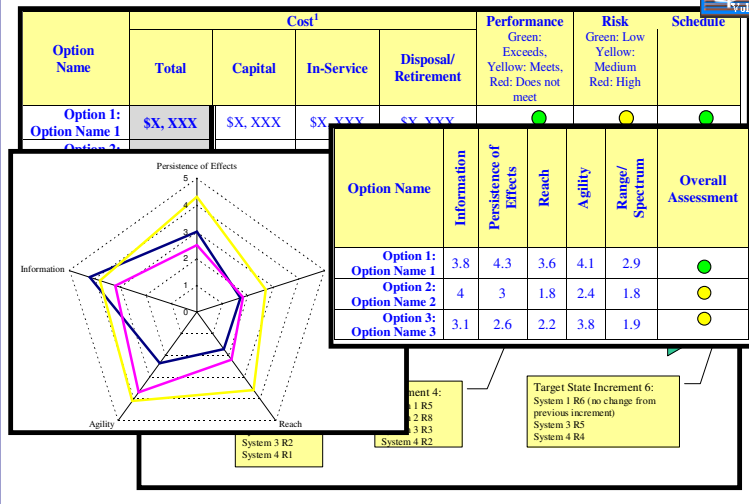
Canada's MOD Experience Capability Engineering



Canadian Department of National Defence is moving towards a 'capability based approach'

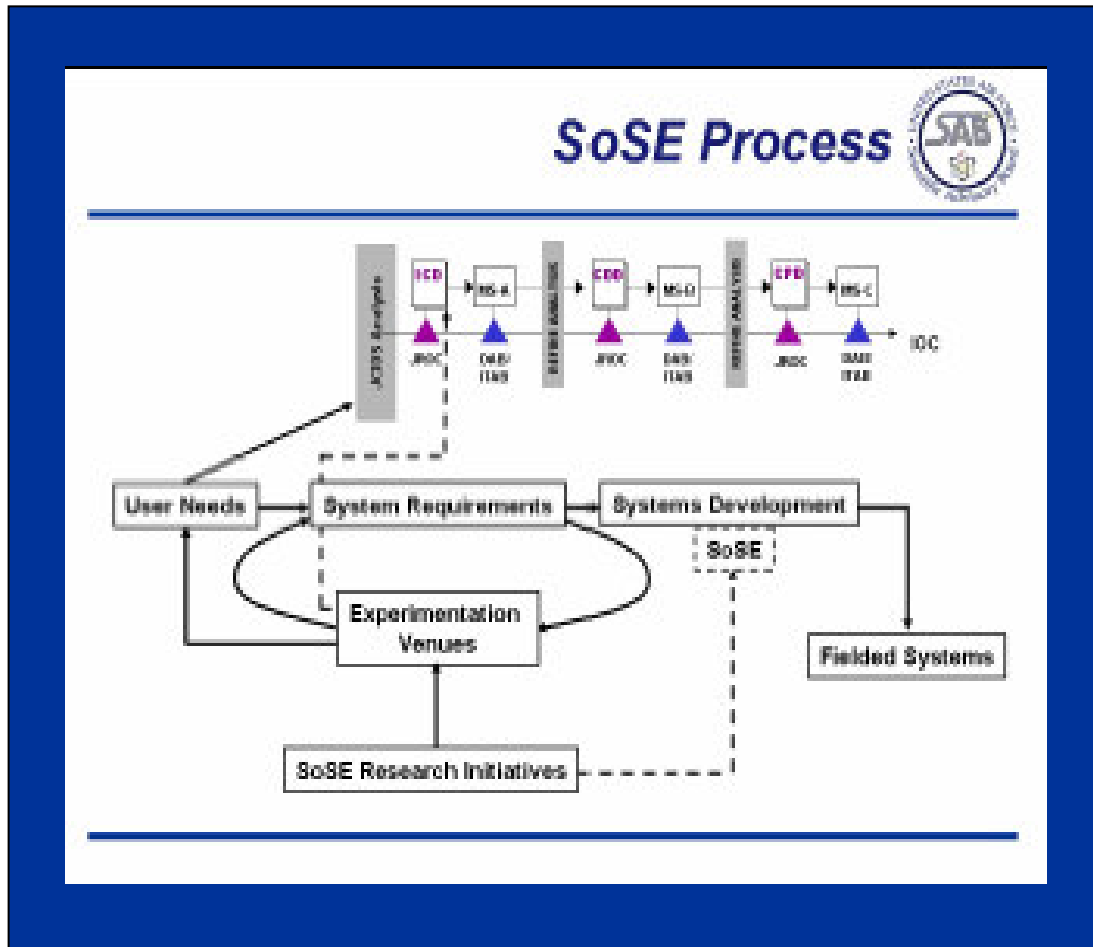
- Began 8 years ago
- Response to a lack of
 - Linkage between leadership strategy and acquisition programs
 - Coherence across acquisition programs
- Still working toward integrated process

Cap Eng Process Deliverables



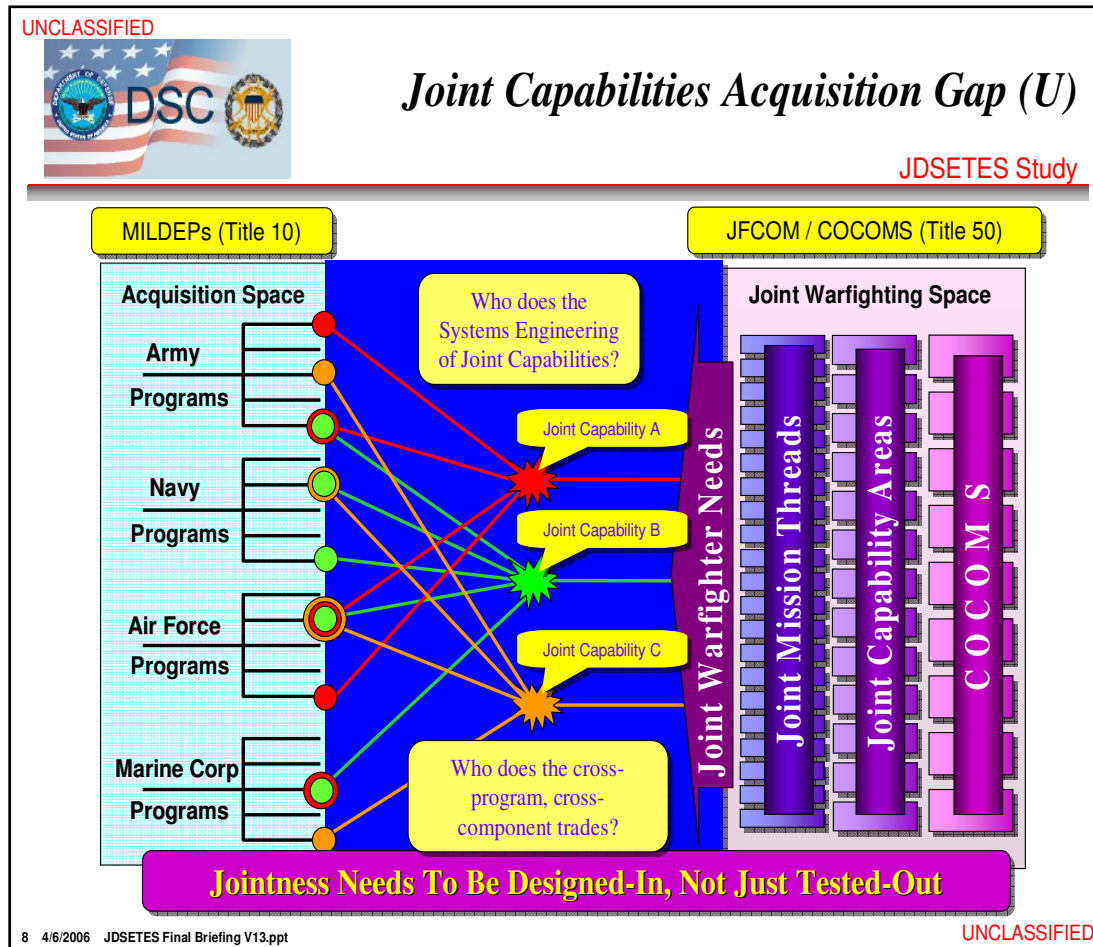
- One focus of their efforts is Capability Engineering (CE)
 - Application of SE processes to capabilities [discussed at MORS CBPII]
- Concepts have been developed and initial applications are underway
- Provides an opportunity for collaboration for US SE work to address SOS

SE Forum Air Force Science Advisory Board on SOS SE*



- Presented to SE Forum
- Emphasized a strong role for **experimentation** in understanding requirements and defining development approaches
- Driven by the
 - New capability is composed of numerous extant systems
 - Understanding opportunities for combined effects requires discovery
- Opportunity to understand
 - Implications of using multiple systems in new ways (second order effects)
 - Users to assess how much is enough

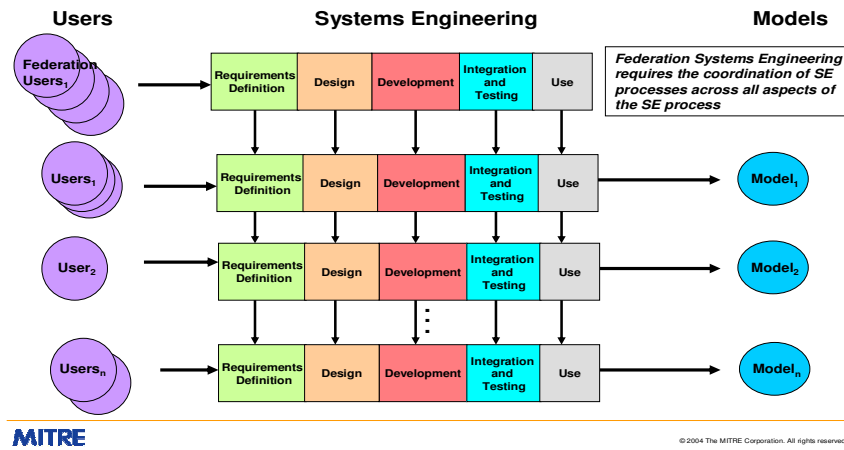
Decision Support Center JDSETES*



- Study sponsored by AT&L and NII
- Calls for emphasis on SE for SOS
- Necessary prerequisite for environments to support SOS SE and test environments

* Joint Distributed Systems Engineering and Test Environment Strategy, Study Draft Final Report, April 2005

Balancing Federation Development and Individual Simulation Development



Experience with M&S SOS

- For years the M&S community has been engineering federations (or systems) of simulations to address evolving, complex M&S needs (e.g. DIS, HLA, TENA)
- Federation development and execution process (FEDEP) provides an experience base for operational systems
- IEEE standards for this process (IEEE 1516) provides insights into what is different about SE needs for composing SOS (M&S federations) vice developing new systems (simulations)

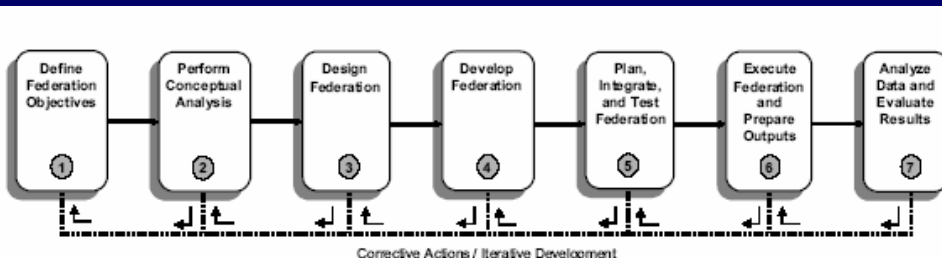
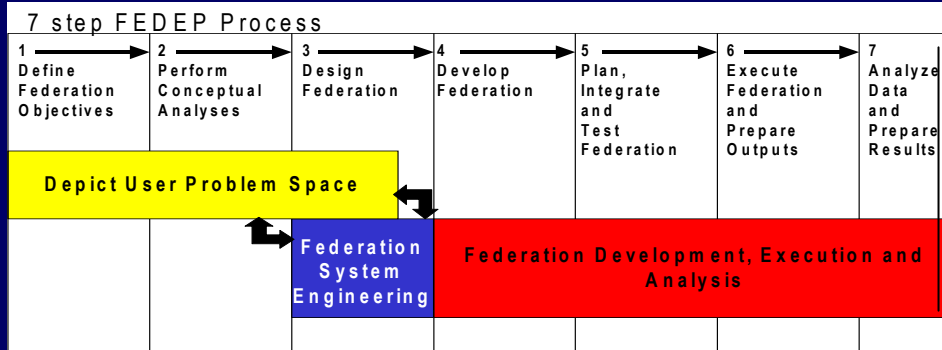
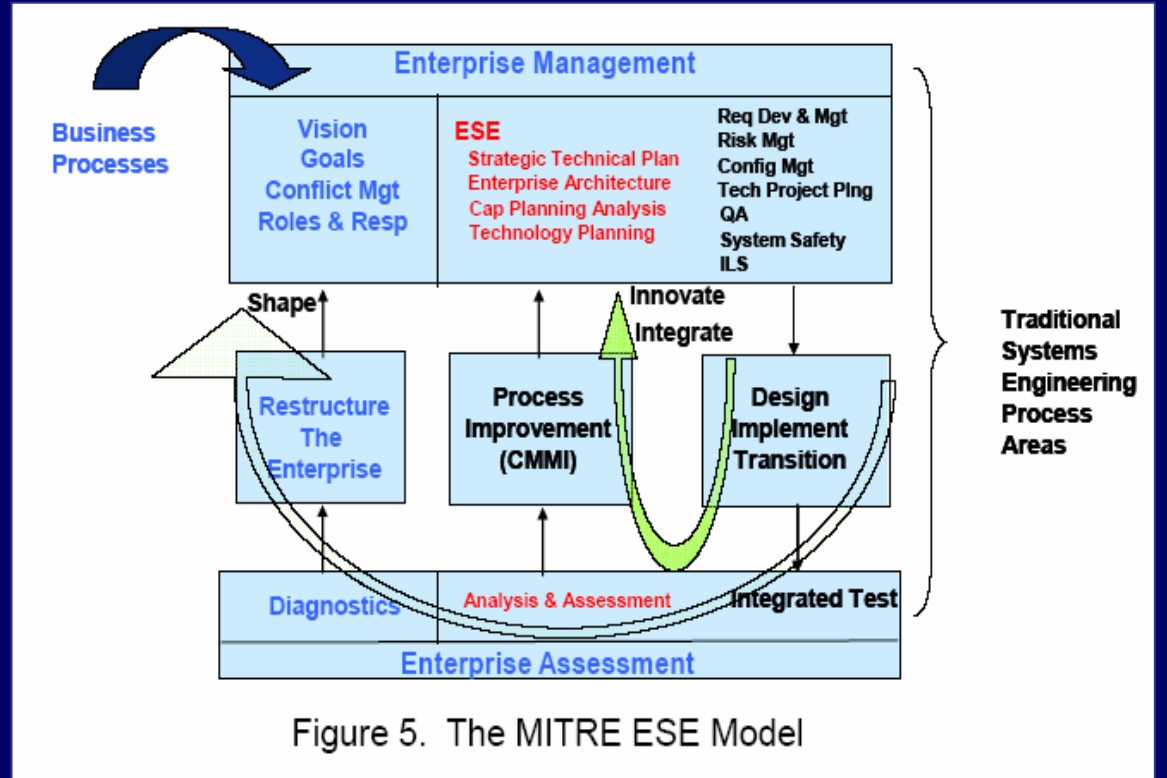
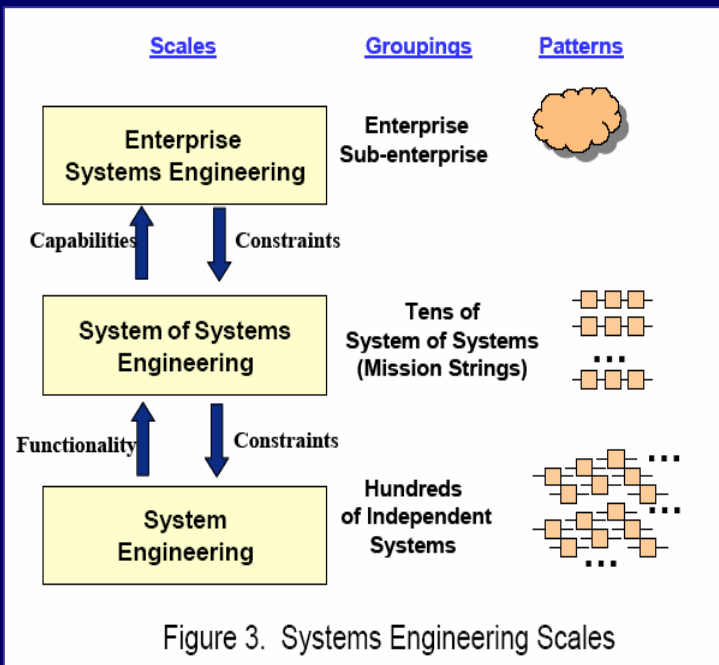


Figure 1—Federation development and execution process (FEDEP), top-level view

1516.3 IEEE Recommended Practice for High Level Architecture (HLA) Federation Development and Execution Process (FEDEP)

MITRE Enterprise Systems Engineering Model*

- Based on experience with increasing complex, **interdependent** systems
- Addresses increases in external influences which constitute the environment in which SE is conducted... **and affect the way SE is conducted**



Areas of General Agreement on SOS SE

- Capabilities which go beyond an individual system need benefits/discipline of SE
- Lack of a capability level management has inhibited progress toward capability areas SE
- SE top level activities apply to SE for capabilities
 - Albeit with different constraints or emphasis
- Major SE issues surround
 - Lack of definition of capability level requirements, needs or objectives
 - Competing demands on systems and management of multiple versions (CM, scheduling)
 - Own requirements
 - Requirements of SOS
 - Requirements of other SOS's
 - Synchronizing development, integration and test
 - Testing, given complexity and scope
- Multiple ownership and control of systems is source of management issues and has implications for SE process

Open Issues

- Approach to capability specification and design
 - Extend standard SE process and do full design for SOS and then assess ways to adapt existing capabilities to meet new needs (Navy NCEP)
 - Conduct design only to first level, integrate current systems, evaluate base level of capability, and improve in areas as needed (Navy NIFCA, M&S Federation)
 - Begin with experimentation as basis for design (AFSAB)
- Balance between 'top down design and engineering' and 'bottom up consensus based collaborative approach'
- Role of 'architecture'
 - Starting point (IT view)
 - Product of SE process (SE view)

Limited experience in DOD to help address these issues

QDR Implementation



Capability Portfolio Management Options

	Status Quo	Alternative Solutions		
		Common Framework (Federated Ownership)	Joint Management Mechanism (Decentralized Execution)	Joint Execution Mechanism
Example	Most Defense Activities (JCIDS uses Capabilities)	✓ Mobility Capability Study ✓ Global Basing ✓ DAB Capability Area Reviews (not same as JCAs)	✓ Joint National Training ✓ Nuclear Portfolio ? ✓ BRAC	✓ MDA ✓ British Model
Roles & Authorities Changes	None	None	Moves Money control	Massive Restructuring
Outcome	Aligns the "Likes"	Provides a Common Decision Framework for Enterprise Level Decisions	Reorganizes Resource Allocation at the Joint/Enterprise Level	Can clearly link strategy, requirements, funding, acquisition and outcomes
Scope of Change	Limited and Marginal	Can be significant, but takes a lot of effort to execute a decision	Depends, Can be significant, establishes enterprise level accountability, less effort to execute	Can be done, butt certainly difficult
Comments	Focused on Programs, "bottoms up" Dominated by Suppliers	Common Facts & Thinking about Portfolios,	Ties Funding Allocation to Portfolios, creates transparency, top down, horizontally integrates	Organizes management and execution around Portfolios under one accountable entity

- QDR focused on need for joint capabilities
- Addresses selected priority areas
- Examines different 'models' for managing joint portfolios
- Joint portfolio management and execution requires coordinated development of interoperable systems

SE Implications

Way Ahead

- Continue investigation and coordination of numerous SoS SE experiences
- Support ongoing capability areas and portfolios
 - Define needs of QDR portfolios
- Leverage OSD SE Forum
 - Linkage to broader SE community
 - Basis for SE guidance and policy updates
 - Develop SoS SE Guide
 - Capture knowledge gained from experiences
 - Augment existing policy and processes

Way Forward: SOS SE Guidebook

Goal: Develop DoD SE guidebook for SoS

Tasks:

- Classify types and approaches of SoS (Enterprise Systems, Adaptive Systems, C2 Systems, ISR Systems, etc.)
- Conduct survey of best commercial and DoD SoS SE practices
- Review and leverage existing policies, procedures and approaches. Example: Navy capability engineering process
- Review results of SE assessments
- Develop list of key planning enablers for successful SoS SE
- Organize process in logical progression steps
- Define boundaries, if any, and relationship to program management
- Develop DoD guide

Deliverables: Final SoS SE guide by end of November 06